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(54) APPAREIL EPITAXIAL EN PHASE VAPEUR ET PROCEDE EPITAXIAL EN PHASE VAPEUR
(54) VAPOR PHASE EPITAXIAL APPARATUS AND VAPOR PHASE EPITAXIAL METHOD

(57)
A vapor phase epitaxial apparatus comprises a sealable reaction furnace, a wafer accommodation body which is installed in the reaction furnace to dispose a wafer at a predetermined position, a gas feeding means for feeding raw gas toward the wafer, and a heating means for heating the wafer. An epitaxial film is formed on a surface of the wafer by feeding the raw gas into the reaction furnace in a high-temperature state while heating the wafer via the wafer accommodation body by the heating means in the reaction furnace. The wafer accommodation body comprises a heat flow control unit having a cavity formed for accommodating the wafer, and a heat flow transmission unit which is joined to the heat flow control unit to transfer the heat to the wafer accommodated in the cavity. The contact thermal resistance of the heat flow control unit with the heat flow transfer unit is set to be not lower than $1.0 \times 10^{-6}$ m2K/W and not greater than $5.0 \times 10^{-3}$ m2K/W, and the heat flow control unit is formed of a material having the thermal conductivity of not smaller than 0.5 times and not greater than 5 times of the thermal conductivity of the wafer disposed on the heat flow transfer unit.

(54) Titre : APPAREIL EPITAXIAL EN PHASE VAPEUR ET PROCEDE EPITAXIAL EN PHASE VAPEUR
(54) Title: VAPOR PHASE EPITAXIAL APPARATUS AND VAPOR PHASE EPITAXIAL METHOD



HEAT TRANSFER ROUTE 2

OVERALL HEAT RESISTANCE
$R_{2total} = R_2 + R_{2a}$
$= R_{2c} + R_{2g} + R_{2p} + R_{2a}$

HEAT TRANSFER ROUTE 1

OVERALL HEAT RESISTANCE
$R_{1total} = R_1 + R_{1a}$
$= R_{1c} + R_{1g} + R_{1w} + R_{1a}$
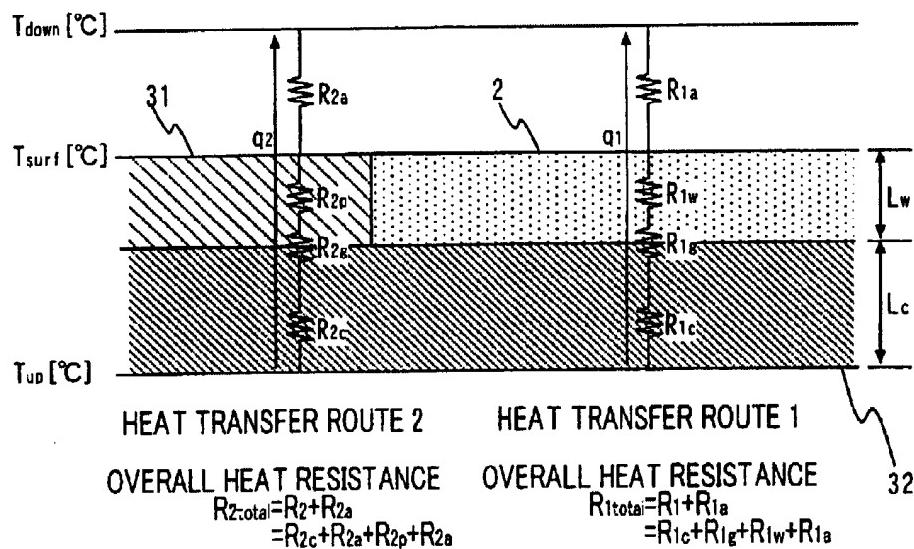
(57) Abrégé/Abstract:
A vapor phase epitaxial apparatus comprises a sealable reaction furnace, a wafer accommodation body which is installed in the reaction furnace to dispose a wafer at a predetermined position, a gas feeding means for feeding raw gas toward the wafer, and a heating means for heating the wafer. An epitaxial film is formed on a surface of the wafer by feeding the raw gas into the reaction furnace in a high-temperature state while heating the wafer via the wafer accommodation body by the heating means in the reaction furnace. The wafer accommodation body comprises a heat flow control unit having a cavity formed for accommodating the wafer, and a heat flow transmission unit which is joined to the heat flow control unit to transfer the heat to the wafer accommodated in the cavity. The contact thermal resistance of the heat flow control unit with the heat flow transfer unit is set to be not lower than $1.0 \times 10^{-6}$ m$^2$K/W and not greater than $5.0 \times 10^{-3}$ m$^2$K/W, and the heat flow control unit is formed of a material having the thermal conductivity of not smaller than 0.5 times and not greater than 5 times of the thermal conductivity of the wafer disposed on the heat flow transfer unit.

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ABSTRACT

A vapor-phase growth apparatus includes: a reaction
furnace which is hermetically closable, a wafer container
which is disposed in the reaction furnace, for disposing a
wafer at a predetermined position, a gas supply member for
supplying a source gas toward the wafer, and a heating member
for heating the wafer, wherein the apparatus is designed to
form a grown film on a front surface of the wafer by supplying
the source gas in a high temperature state while the heating
member heats the wafer in the reaction furnace through the
wafer container. The wafer container includes: a heat flow
control section having a space for disposing a wafer; and a
heat flow transmitting section joined to the heat flow control
section, for transmitting heat to the wafer disposed in the
space; and contact heat resistance $R_q$ between the heat flow
control section and the heat flow transmitting section is not
less than $1.0 \times 10^{-6}$ m$^2$K/W to not more than $5.0 \times 10^{-3}$ m$^2$K/W, and
the heat flow control section is made of a material having a
coefficient of thermal conductivity which is not less than 5
times to not more than 20 times that of the wafer disposed on
the heat flow transmitting section.

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DESCRIPTION

VAPOR-PHASE GROWTH APPARATUS AND VAPOR-PHASE GROWTH METHOD

Technical Field

The present invention relates to a vapor-phase growth apparatus and a vapor-phase growth method, for growing a thin film of compound semiconductor or the like on a surface of a wafer in a vapor phase, while heating the wafer under a supply of a source gas in a high temperature state, and in particular to material characteristics of a wafer container for disposing wafers thereon.

Background Art

Vapor-phase growth process is currently utilized in various industrial fields. Needless to say, in the vapor-phase growth, advanced uniformities in thickness, composition and doping concentration of a film grown on the wafer over the entire surface thereof are essential matters. Achievement of thermal uniformity in wafer heating is therefore recognized as the most important elementary technology as one means for realizing the aforementioned uniformities over the entire surface.

FIG. 1 is a sectional view showing an exemplary constitution of a general vapor-phase growth apparatus. As shown in FIG. 1, a vapor-phase growth apparatus 100 comprises

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a reaction furnace 1, a wafer holder 3 for disposing wafers 2

thereon, a susceptor 4 for placing the wafer holder 3 thereon,

a heater 5 disposed below the susceptor 4, a rotary mechanism

6 for supporting the wafer holder 3 and the susceptor 4 to

allow them to rotate freely, a gas introducing duct 7 for

supplying a source gas and a carrier gas therethrough, a gas

exhaust duct 8 for discharging the non-reacted gas, and the

like.

FIG. 9 is an enlarged view for showing a detailed

construction of the wafer holder 3, where (a) is a plan view,

and (b) is a sectional view taken along the line A-A in FIG. 9.

In one surface of the wafer holder 3, a plurality of (six in

FIG. 2) circular pocket holes 3a are formed for disposing the

wafers 2 therein, to be arranged along a single circumference

on the surface. The other surface of the wafer holder 3 is in

contact with the susceptor 4. The wafer holder 3 may be

composed of one or more members. Generally, it is composed of

a single member, as shown in FIG 9.

The susceptor 4 herein is made of a material having a

large coefficient of thermal conductivity (e.g., molybdenum)

in order to uniformly transfer heat from the heater 5. It is

also general to use graphite, molybdenum or the like, having a

large coefficient of thermal conductivity for the wafer holder

3.

In the vapor-phase growth apparatus having such a

structure described above, heat is transferred to the wafer 2

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through the susceptor 4 and wafer holder 3 by heating the susceptor 4 from the lower side thereof by using the heater 5, to thereby heat the wafer 2 up to a predetermined temperature. Vapor-phase growth of a thin film is carried out by rotating the susceptor 4 at a predetermined number of rotation with the aid of a rotating mechanism 6 while uniformly supplying source gas and carrier gas, introduced through a gas introducing duct 7 toward the front surface of the wafer 2.

It was, however, found from an experiment of the present inventors that, in the aforementioned vapor-phase growth apparatus 100, the front surface temperature of the wafer 2 became lower than that of the wafer holder 3, and that the temperature of the circumferential portion of the wafer 2 consequently became higher than that of the central portion of the wafer 2, by the effect of the temperature of the wafer holder 3. In other words, it was found to be difficult for the conventional vapor-phase growth apparatus 100 to form a thin film with a high uniformity over the entire surface of the wafer 2 by vapor-phase growth since in-plane temperature distribution of the wafer 2 could not be uniform.

The present invention has been developed in order to solve the aforementioned problems. An object of the invention is therefore to provide a vapor-phase growth apparatus and a vapor-phase growth method which are capable of allowing a thin film to grow in a vapor phase so as to achieve a desirable uniformity over the entire surface of a wafer.

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Disclosure of the Invention

In accordance with the invention, the vapor-phase growth apparatus comprises: at least a reaction furnace which can be tightly closed, a wafer container which is disposed in the reaction furnace, for disposing a wafer at a predetermined position thereon, a gas supply member for supplying a source gas toward the wafer, and a heating member for heating the wafer; the apparatus being designed to form a grown film on a front surface of the wafer by heating the wafer in the reaction furnace through the wafer container while supplying the source gas in a high temperature state, wherein the wafer container comprises: a heat flow control section having a space formed, for disposing a wafer therein; and a heat flow transmitting section which is joined to the heat flow control section, for transmitting heat to the wafer disposed in the space, and a uniform heat resistance $R_g$ exists between flat or curved surfaces, of the heat flow control section and the heat flow transmitting section, in close proximity to each other.

According to the wafer container having such a structure, it is possible to adjust the ratio $R_2/R_1$ easily, where $R_1$ is a heat resistance in a heat transfer route from a rear surface of the heat flow transmitting section to the front surface of the wafer, and $R_2$ is a heat resistance in a heat transfer route from the rear surface of the heat flow transmitting section to a front surface of the heat flow control section.

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Preferably, the heat resistance ratio $R_2/R_1$ is not less than 0.8 and not more than 1.2.

This almost equalizes the heat resistances in the individual heat transfer routes each other and thus ensures similar heat transfer during heat transfer from the rear surface of the wafer container (the rear surface of the heat flow transmitting section) toward the front surfaces of the wafer and of the wafer container (the front surface of the heat flow control section), and this consequently equalizes achievable temperatures of the surfaces of the wafer and the wafer container. This successfully prevents the surface temperature at the circumferential portion of the wafer from rising higher than the surface temperature at the center of the wafer, which is caused by temperature difference between the surfaces of the wafer and the wafer container. Thus, it becomes possible to keep a uniform in-plane temperature distribution of the wafer. As a consequence, a thin film having a desirable uniformity can grow in the vapor phase over the entire surface of the wafer.

The heat resistance $R_g$ is not less than $1.0 \times 10^{-6}$ $m^2K/W$ and not more than $5.0 \times 10^{-3}$ $m^2K/W$; otherwise a clearance distance between the heat flow control section and the heat flow transmitting section may be approximately uniform and in a range of 0.001mm to 1mm. Accordingly, because the heat resistance $R_g$ comes to be approximately equal to the contact heat resistance between the heat flow transmitting section and

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the wafer, it is possible to adjust the ratio $R_2/R_1$ easily.

Further, preferably, the heat flow control section is made of a material having a coefficient of thermal conductivity which is not less than 0.5 times that of the wafer disposed on the heat flow transmitting section and not more than 20 times thereof. Although it is not limited, the heat flow control section 31 may be made of any material, as far as the material has characteristics giving no adverse effect on thin film growth or on the environment of the reactor.

Preferably, the heat flow transmitting section is made of a material having a coefficient of thermal conductivity higher than that of wafer, for example, a material having a coefficient of thermal conductivity which is not less than 50W/mK and not more than 450W/mK.

For example, the heat flow control section may be made of any one of amorphous carbon, aluminum nitride, graphite, silicon, silicon carbide, molybdenum, pyrolitec boron nitride, and alumina; and the heat flow transmitting section may be made of any one of molybdenum, graphite, gold, and silver.

A vapor-phase growth apparatus comprising the above described structure is made to form a grown film on a front surface of the wafer by heating the wafer in the reaction furnace through the wafer container while supplying the source gas in a high temperature state, wherein a temperature difference between a front surface of the wafer container and

a front surface of the wafer during growing a thin film in vapor-phase is within 2°C. Accordingly, because it is possible to keep a uniform in-plane temperature distribution of the wafer, a thin film having a desirable uniformity can be grown in the vapor phase over the entire surface of the wafer.

Next, the progress that the present invention has been developed will be described, as follows.

As for a reason why the surface temperature of the wafer 2 tends to become lower than that of the wafer holder 3, the present inventors placed a focus on the difference between heat transfer routes inside the wafer 2 and wafer holder 3. That is, the present inventors considered that because the wafer 2 and wafer holder 3 generally differ from each other in materials, so that the same heat transfer cannot be performed in the routes. This causes a difference between achievable surface temperatures of the wafer and the wafer holder.

FIG. 10 is a schematic view showing heat resistances in the wafer 2 and wafer holder 3. In FIG. 10, $T_{up}$ denotes rear surface temperature of the wafer holder 3, $T_{surf}$ denotes a front surface temperature of the wafer 2 or wafer holder 3, and $T_{down}$ denotes a temperature at an imaginary plane (referred to as "virtual boundary plane", hereinafter) set at a position being away from the surfaces of the wafer 2 and wafer holder 3 by a predetermined distance. As shown in FIG. 10, heat transfer toward the front surface of the wafer 2 is established along a heat transfer route 1 which originates from the rear surface of the wafer holder 3 and is directed through the wafer holder

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3 itself and the wafer 2 to reach the virtual boundary plane,
and heat transfer toward the front surface of the wafer holder
3 is established along a heat transfer route 2 which
originates from the rear surface of the wafer holder 3 and is
directed through the wafer holder 3 itself to reach the
virtual boundary plane. As described above, the wafer 2 and
wafer holder 3 differ from each other in the heat transfer
route toward the respective surfaces thereof.

That is, as known from the schematic view of heat
resistance of the wafer 2 and wafer holder 3 shown in FIG. 10,
the heat resistance $R_1$ for the heat transfer route 1 is equal
to the sum of heat resistance $R_{1c}$ for the portion of wafer
holder 3, the contact heat resistance $R_{1g}$ between the wafer
holder 3 and wafer 2, and the heat resistance $R_{1w}$ for the
portion of wafer 2; and the heat resistance $R_2$ for the heat
transfer route 2 is equal to the heat resistance $R_{2c}$ for the
portion of wafer holder 3.

By the way, heat resistance R is given by the equation
(1) below:

$R = L/k$      (1)

    $R \, [m^2 K/W]$ : a heat resistance

    $L \, [m]$ : a thickness of a material in the direction
of heat flow

    $k \, [W/m \cdot K]$ : a coefficient of thermal conductivity

Heat resistances $R_1$ and $R_2$ are then expressed by the
equations below:

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$$R_1 = R_{1c} + R_{1g} + R_{1w} = L_c/k_{1c} + R_{1g} + L_w/k_{1w} \qquad (2)$$

$$R_2 = R_{2c} = L_c/k_{2c} + L_w/k_{2c} \qquad (3)$$

$$(k_{1c} = k_{2c})$$

It is to be noted now that a relation can be written as $L_w/k_{1w} > L_w/k_{2c}$ because coefficient of thermal conductivity $k_{1w}$ of the wafer 2 (InP, GaAs, etc.) is extremely smaller than coefficient of thermal conductivity $k_{2c}$ of the wafer holder 3 (graphite, molybdenum, etc.), and contact heat resistance $R_{1g}$ arises at the contact plane between the wafer 2 and wafer holder 3, so that $R_2$ is apparently smaller than $R_1$.

$$R_1 > R_2 \qquad (4)$$

It is also known that heat transfer is subject to heat flux in the heat transfer route. The heat flux generally refers to as the amount of energy (heat flow) flowing in a unit area (unit: $m^2$), and is given by equation (5) below:

$$q = -1/R_{total} (T_{down} - T_{up}) \qquad (5)$$

$q [W/m^2]$ : a heat flux

$R_{total} [m^2K/W]$ : an overall heat transfer

$T_{up} [K]$ : an upstream temperature

$T_{down} [K]$ : a downstream temperature.

In FIG. 10, overall heat resistances $R_{1total}$ and $R_{2total}$ in the heat transfer routes 1 and 2 are given by the equations below:

$$R_{1total} = R_1 + R_{1a} \qquad (6)$$

$$R_{2total} = R_2 + R_{2a} \qquad (7)$$

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(where, $R_{1a} = R_{2a}$)


The foregoing equations (4), (6) and (7) give a relation of $R_{1total} > R_{2total}$. Therefore, the heat flux $q_1$ in the heat transfer route 1 becomes smaller than the heat flux $q_2$ in the heat transfer route 2.

$$q_2 > q_1 \qquad (8)$$

Furthermore, the heat fluxes $q_1$ and $q_2$ can be represented as the equations below using the surface temperature $T_{1surf}$ of the wafer 2 and the surface temperature $T_{2surf}$ of the wafer holder 3:

$$q_1 = -(T_{down} - T_{1surf})/R_{1a} \qquad (9)$$
$$q_2 = -(T_{down} - T_{2surf})/R_{2a} \qquad (10)$$


It is derived from the foregoing equations (8), (9) and (10) that the surface temperature $T_{1surf}$ of the wafer 2 is lower than the surface temperature $T_{2surf}$ of the wafer holder 3.

$$T_{2surf} > T_{1surf} \qquad (11)$$


It was thus found that, in the conventional vapor-phase growth apparatus, the difference between the surface temperatures $T_{1surf}$ and $T_{2surf}$ is caused by a large difference in the coefficients of thermal conductivity between the wafer 2 and wafer holder 3.

The present inventors therefore studied a method of reducing the difference between the surface temperature $T_{1surf}$ of the wafer 2 and the surface temperature $T_{2surf}$ of the wafer

holder 3, and based on the above equations (5) to (10), and reached an idea that close equalization of the heat resistances $R_1$ and $R_2$ in the individual heat transfer routes would be successful (that is, to set heat resistance ratio $R_2/R_1$ close to 1).

The present inventors has found a method in which the wafer holder 3 is composed of two members, i.e., a heat flow control section 31 and a heat flow transmitting section 32.

In the case, the schematic view of heat resistance is shown in FIG. 3, and a heat resistance $R_1$ and a heat resistance $R_2$ are given by the equations below:

$$R_1 = R_{1c} + R_{1g} + R_{1w} = L_c/k_{1c} + R_{1g} + L_w/k_{1w} \qquad (12)$$
$$\text{(equivalent to the equation (2))}$$
$$R_2 = R_{2c} + R_{2g} + R_{2w} = L_c/k_{2c} + R_{2g} + L_w/k_{2p} \qquad (13)$$
$$(k_{1c}=k_{2c})$$

That is, it is possible to bring near the heat resistance values $R_1$ and $R_2$ to each other, by bringing the value of contact heat resistance $R_{1g}$ between the wafer 2 and the heat flow transmitting section 32 near the value of contact heat resistance $R_{2g}$ between the heat flow control section 31 and the heat flow transmitting section 32 and also by bringing the value of coefficient of thermal conductivity $k_{1w}$ of the wafer 2 near the value of coefficient of thermal conductivity $k_{2p}$ of the heat flow control section 31.

The present invention has been developed based on the

aforementioned findings, and is to provide a vapor-phase

growth apparatus 100 in which the wafer holder 3 includes: a

heat flow control section having a space formed, for disposing

a wafer 2 therein; and a heat flow transmitting section which

is joined to the heat flow control section, for transmitting

heat to the wafer disposed in the space, and a uniform heat

resistance $R_{2g}$ exists between flat or curved surfaces, of the

heat flow control section and the heat flow transmitting

section, in close proximity to each other, so that the ratio

$R_2/R_1$, is not less than 0.8 and not more than 1.2.

In the present invention, the heat resistance $R_g$ may be

not less than $1.0 \times 10^{-6}$ m$^2$K/W and not more than $5.0 \times 10^{-3}$ m$^2$K/W;

otherwise a clearance distance between the heat flow control

section and the heat flow transmitting section may be

approximately uniform and in a range of 0.001mm to 1mm.

Accordingly, it is possible to obtain approximately equal

contact heat resistances $R_{1g}$ and $R_{2g}$. Further, the heat flow

control section may be made of a material having a coefficient

of thermal conductivity which is not less than 0.5 times that

of the wafer disposed on the heat flow transmitting section

and not more than 20 times thereof, to bring the value of

coefficient of thermal conductivity $k_{1w}$ of the wafer 2 near the

value of coefficient of thermal conductivity $k_{2p}$ of the heat

flow control section 31.

Although the heat resistance ratio $R_2/R_1$ can be

approximated to 1 also by raising a value of $L_w$ or $L_c$ in the

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equations (12) and (13), this is less feasible due to problems in temperature control, in space efficiency of the apparatus and in costs, so that a material of the heat flow control section 31 was selected such as one having a coefficient of thermal conductivity close to that of the wafer 2, as a more practical strategy.

Brief Description of the Drawings

FIG. 1 is a sectional view showing a schematic construction of the vapor-phase apparatus according to the present embodiment;

FIG. 2 is an enlarged views showing a detailed construction of the wafer holder 3 which is composed of a heat flow control section and a heat flow transmitting section, where (a) is a plan view, and (b) is a sectional view taken along the line A-A;

FIG. 3 is a schematic view for explaining heat resistance of the wafer 2 and wafer holder 3 in the case where the wafer holder 3 is composed of a heat flow control section and a heat flow transmitting section;

FIG. 4 is a schematic analytical model view showing a region around the wafer 2 and wafer holder 3 of the vapor-phase growth apparatus 100 according to the embodiment;

FIG. 5 shows an analytical result of temperature distribution inside the wafer and wafer holder in the embodimenta wafer holder which is composed of a heat flow

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control section and a heat flow transmitting section is used;

FIG. 6 shows an analytical result of temperature distribution inside the wafer and wafer holder in a comparative embodiment where a graphite-made wafer holder is used;

FIG. 7 shows analytical results of surface temperature distribution of the wafer 2 and wafer holder 3 in the embodiment; and

FIG. 8 shows analytical results of surface temperature distribution of the wafer and wafer holder in the comparative embodiment.

FIGS. 9 is an enlarged views showing a detailed construction of an earlier developed wafer holder 3, where (a) is a plan view, and (b) is a sectional view taken along the line A-A; and

FIG. 10 is a schematic view for explaining heat resistance of the wafer 2 and wafer holder 3 in an earlier developed vapor-phase growth apparatus.


Best Mode for Carrying out the Invention

An embodiment of the vapor-phase growth apparatus (MOCVD apparatus) of the present invention will be described below referring to the attached drawings.

FIG. 1 is a sectional view showing a schematic construction of the vapor-phase growth apparatus according to the present embodiment. FIG. 2 is an enlarged view showing a

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detailed construction of the wafer holder 3 in the present

invention, where (a) is a plan view, and (b) is a sectional

view taken along the line A-A.

In the earlier development, the wafer holder 3 which is a

wafer container was made of a material having a large

coefficient of thermal conductivity, such as graphite. The

vapor-phase growth apparatus of the embodiment is different

from the earlier development in that the wafer container

comprises: a heat flow transmitting section 32 made of a

material having a large coefficient of thermal conductivity,

such as graphite; and a heat flow control section 31 made of

amorphous carbon (abbreviated as α-carbon, hereinafter) or the

like, having a coefficient of thermal conductivity relatively

near that of the wafer.

As shown in FIG. 1, the vapor-phase growth apparatus 100

comprises a reaction furnace 1, a wafer holder 3 for disposing

wafers 2 thereon, a susceptor 4 for placing the wafer holder 3

thereon, a heater 5 disposed below the susceptor 4, a rotary

mechanism 6 for supporting the wafer holder 3 and the

susceptor 4 in a freely rotatable manner, a gas introducing

duct 7 for supplying a source gas and a carrier gas

therethrough, and a gas exhaust duct 8 for discharging the

non-reacted gas.

Each of wall members of the vapor-phase growth apparatus

100 is typically composed of a stainless steel. The gas

introducing duct 7 is disposed at the vicinity of the center

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portion of the upper wall member, and introduces a Group XIII

(IIIB) source gas such as trimethyl indium (TMI), trimethyl

aluminum (TMA1) or trimethyl gallium (TMG); a Group XV (VB)

source gas such as arsine ($AsH_3$) or phosphine ($PH_3$); and an

inert gas such as hydrogen ($H_2$) as a carrier gas into the

reaction furnace.

The wafer holder 3 is composed of a member which

comprises a heat flow transmitting section 32 made of graphite

and formed in a disk shape, and a heat flow control section 31

made of amorphous carbon which is formed on the heat flow

transmitting section 32 as a body. The wafer holder 3 is

placed on the susceptor 4. In the heat flow control section 31,

a plurality of (six in FIG. 2) circular pocket holes

(recesses) 3a for containing the wafers 2 therein, are formed

along a single circumference. The susceptor 4 is composed of a

material having a large coefficient of thermal conductivity

(e.g. molybdenum) in order to uniformly transfer heat from the

heater 5, and is supported by the rotary mechanism 6 in a

freely rotatable manner. Below the susceptor 4, the heater 5

for heating the wafer 2 is concentrically arranged.

Although it was a general practice to use graphite or

molybdenum having a large coefficient of thermal conductivity,

for the wafer holder 3 in the earlier developed vapor-phase

growth apparatus, the wafer holder 3 in the vapor-phase growth

apparatus 100 according to the present embodiment comprises a

heat flow transmitting section 32 made of graphite, and a heat

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flow control section 31 made of α-carbon.

Concretely, by using α-carbon having a coefficient of
thermal conductivity of about 10 W/m·K for the heat flow
control section 31, the coefficient of thermal conductivity of
the wafer 2 placed on the wafer holder 3 and the coefficient
of thermal conductivity of the wafer holder 3 come to be
approximately equal to each other. Because the coefficient of
thermal conductivity of an InP wafer is 14.3 W/m·K which is
estimated as approximately 0.7 times that of α-carbon.

The clearance between the heat flow control section 31
and the heat flow transmitting section 32 is approximately
uniform in a range of 0.01mm to 1mm, and the contact heat
resistance thereof is not less than $1.0 \times 10^{-6}$ $m^2K/W$ and not more
than $1.0 \times 10^{-1}$ $m^2K/W$.

Such a construction almost equalizes the heat resistances
for the individual heat transfer routes from the heater 5 to
the front surface of the wafer 2 and to the front surface of
the wafer holder 3, through the susceptor 4 and wafer holder 3,
and this consequently equalizes achievable temperatures of the
surfaces of the wafer 2 and of the wafer container 3. This
successfully prevents the surface temperature at the
circumferential portion of the wafer from rising higher than
the surface temperature at the center of the wafer, which is
caused by temperature difference between the surfaces of the
wafer 2 and the wafer container 3. Thus, it becomes possible
to keep a uniform in-plane temperature distribution of the

wafer 2.

The heat flow transmitting section 32 may be made of not only graphite but also, for example, molybdenum, gold, silver or the like. The heat flow control section 31 may be made of not only α-carbon but also aluminum nitride, graphite, silicon, silicon carbide, molybdenum, pyrolitec boron nitride, alumina or the like.

The gas exhaust duct 8 is disposed at the bottom of the reaction furnace 1. A source gas introduced into the reaction furnace 1 from an introduction port through the gas introducing duct 7 is decomposed in the upstream side of the reaction furnace, and is then flown to the downstream side to form a thin film on the wafers 2. The non-reacted source gas is discharged out through an exhaust port and the gas exhaust duct 8, together with the carrier gas.

Although not shown in the drawings, water-cooled jackets are provided typically on the outer periphery of the rotary mechanism 6 and on the lower outside wall of the reaction furnace. These water-cooled jackets and heater 5 control the temperature inside the reaction furnace 1.

In the vapor-phase growth apparatus 100 having the above-described construction, heat is transferred to the wafer 2 through the susceptor 4 and the wafer holder 3 under heating of the susceptor 4 from the lower side thereof by using heater 5, to thereby heat the wafer 2 to a predetermined temperature. Vapor-phase growth of a thin film is carried out by rotating

the susceptor 4 at a predetermined number of rotation with the

aid of a rotating mechanism 6 while uniformly supplying a

source gas and carrier gas introduced through a gas

introducing duct 7 to the upper surface of the wafers 2. Since

temperatures of the upper surface of the wafer 2 and the upper

surface of the wafer holder 3 (heat flow control section 31)

herein become almost equivalent each other, the in-plane

temperature distribution of the wafer 2 becomes uniform, and

this allows vapor-phase growth of a thin film having an

excellent uniformity.

Next paragraphs will describe simulation results of heat

transfer examined using the vapor-phase growth apparatus of

the embodiment, in order to clarify specific features of the

present invention. Also a similar simulation of heat transfer

using the earlier developed vapor-phase growth apparatus was

carried out as a comparative embodiment.

In the simulation, the wafer 2 and the vicinity thereof

in the vapor-phase growth apparatus 100 were modeled, and

three-dimensional heat transfer analysis based on the finite

volume method was carried out. A wafer holder 3 which includes

a heat flow transmitting section 32 made of graphite and a

heat flow control section 31 made of α-carbon, was used in the

embodiment, and a graphite-made wafer holder 3 was used in a

comparative embodiment.

FIG. 4 is a schematic analytical model view showing a

region around the wafer 2 and wafer holder 3 (having an

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outward width of 10 mm from the periphery of wafer) of the

vapor-phase growth apparatus 100. As shown in FIG. 4, a

distance from the bottom surface of the wafer holder 3 to the

wafer 2 was defined as 6.4 mm. The wafer 2 was an InP wafer

having a thickness of 0.5 mm and an inner diameter of 50 mm (2

inches), and the reaction furnace 1 was conditioned to have a

hydrogen atmosphere. The number of meshes for the analysis was

defined as about 6,000,000 meshes.

The contact heat resistance ($R_{1g}$) between the wafer 2 and

the heat flow transmitting section 32, and the contact heat

resistance ($R_{2g}$) between the heat flow control section 31 and

the heat flow transmitting section 32 were defined as $2.0 \times 10^{-4}$

$m^2 K/W$. It is to be noted that the contact heat resistance $R_{1g}$

is affected by the flatness, surface roughness and coefficient

of thermal diffusion of the material, of the members

contacting with each other, and it can further be reduced by

reducing the distance between the contact surfaces.

The analytical conditions further includes boundary

conditions of 45°C for the boundary plane of hydrogen gas

located 35 mm above the wafer 2, and of 650 °C for the boundary

(rear surface) of the wafer holder 3.

In the heat transfer analysis of this model, hydrogen was

approximately assumed as a solid, since hydrogen having a

small Prandtl number shows thermal diffusion which prevails

over viscous diffusion, and since effects of advection is

negligible in a region having a relatively small Reynolds

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number in the laminar flow region.

The following physical property values were used for the present analysis.

TABLE 1

| | HYDROGEN | GRAPHITE (COMPARATIVE EXAMPLE) | α-CARBON (EXAMPLE) | InP |
|---|---|---|---|---|
| DENSITY [kg/m³] | 0.00259 | 2000 | 1550 | 4787 |
| SPECIFIC HEAT [J/kgK] | 14500 | 1000 | 1000 | 368 |
| COEFFICIENT OF THERMAL CONDUCTIVITY [W/m·K] | 0.4048 | 100 | 10 | 14.3 |

FIG. 5 shows an analytical result of temperature distribution within the wafer 2 and wafer holder 3 in an Example where a wafer holder 3 comprising a heat flow control section and a heat flow transmitting section is used, and FIG. 6 shows an analytical result of temperature distribution within the wafer 2 and wafer holder 3 in a Comparative Example where an α-carbon-made wafer holder 3 is used. It is to be noted that FIGS. 5 and 6 show enlarged views of the boundary portion between the wafer 2 and wafer holder 3 in order to clarify the analytical results.

FIG. 7 shows analytical results of surface temperature distribution of the wafer 2 and wafer holder 3 in the Example, and FIG. 8 shows analytical results of surface temperature distribution of the wafer 2 and wafer holder 3 in the Comparative Example. It is to be noted that FIGS. 7 and 8 show the surface temperature measured at positions along the

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direction of diameter assuming the center of the wafer as zero.

In the Example, as shown in FIG. 5, the temperature gradients in the wafer 2 and the heat flow transmitting section 32 are almost equivalent, and a parallel and uniform isothermal lines distribution is observed in the wafer 2. On the other hand in Comparative Example, as shown in FIG. 6, the temperature gradients in the wafer 2 and the upper portion of the wafer holder 3 are quite different from each other. In the wafer 2, temperature increases toward the peripheral portion from the central portion. This indicates that, in Example, similar heat transfer is established even if the heat transfer route differs.

Heat resistance ratio $R_2/R_1$ was found to be 1.06 in Example, but 0.24 in Comparative Example.

It was also found for Example shown in FIG. 7 that each of the front surface temperatures of the wafer and of the wafer holder (heat flow control section) was the same at 634.0°C, whereas it was found for Comparative Example shown in FIG. 8 that the front surface temperature of the wafer was 636.0°C, and the front surface temperature of the wafer holder was 638.0°C. That is, the difference between them is about 2.0°C. It was thus made clear that the present Example showed a smaller difference in the front surface temperatures between the circumferential portion (22 to 25 mm) and the central portion (around 0) of the wafer 2, and that the in-plane temperature distribution of the wafer 2 was improved to attain

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uniformity.

As described above, Example was successful in keeping uniformity of the in-plane temperature distribution of the wafer 2 because the surface temperature in the circumferential portion of the wafer 2 became less likely to be affected by the surface temperature of the wafer holder 3. As a result, the present invention is successful in proceeding vapor-phase growth of a thin film which has a desirable uniformity over the entire surface of the wafer.

According to the present embodiment, because the vapor-phase growth apparatus 100 was designed so that the wafer container comprises: a heat flow control section having a space formed, for disposing a wafer therein; and a heat flow transmitting section which is joined to the heat flow control section, for transmitting heat to the wafer disposed in the space; and the contact heat resistance between the heat flow transmitting section and the heat flow control section is not less than $1.0 \times 10^{-6}$ $m^2K/W$ and not more than $5.0 \times 10^{-3}$ $m^2K/W$, and the heat flow control section is made of a material having a coefficient of thermal conductivity which is not less than 0.5 times that of the wafer disposed on the heat flow transmitting section and not more than 20 times thereof. As a result, this almost equalizes the heat resistances for the individual heat transfer routes to each other during heat transfer from the rear surface of the wafer container (the rear surface of the heat flow transmitting section) to the front surfaces of the

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wafer and of the wafer container (the front surface of the
heat flow control section).

That is, because heat transfer is performed according to
almost equivalent heat flux, it is possible equalize
achievable temperatures of the front surfaces of the wafer and
of the wafer container. This successfully prevents the front
surface temperature at the circumferential portion of the
wafer from rising higher than the surface temperature at the
center of the wafer which is caused by temperature difference
between the surfaces of the wafer and the wafer container, and
makes it possible to keep a uniform in-plane temperature
distribution of the wafer. As a result, the present invention
is successful in proceeding vapor-phase growth of a thin film
which has a desirable uniformity over the entire surface of
the wafer.

Industrial Applicability

Although the foregoing paragraphs explained the present
invention conceived by the present inventors mainly referring
to a vertical high-speed-rotating-type, vapor-phase growth
apparatus on which the background of the invention stands, the
present invention is by no means limited to the above type,
and instead applicable to any general vapor-phase growth
apparatuses such as those based on face-down system, lateral
type, autorotation/revolution system, and the like.

The present invention is applicable not only to the case

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where InP wafer is used, but also to cases where a thin film

is grown on wafers such as being comprised of Si, GaAs, GaN,

sapphire, glass, ceramic, and the like. In these cases, it is

also allowable to alter a material composing the wafer holder

3 (or heat flow control section 31) depending on the wafer to

be used.

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CLAIMS


1.    A vapor-phase growth apparatus comprising:

a reaction furnace which is hermetically closable,

a wafer container which is disposed in the reaction

furnace, for disposing a wafer at a predetermined position,

a gas supply member for supplying a source gas toward the

wafer, and

a heating member for heating the wafer,

wherein the apparatus is designed to form a grown film on

a front surface of the wafer by supplying the source gas in a

high temperature state while the heating member heats the

wafer in the reaction furnace through the wafer container,

the wafer container comprises a heat flow control section

having a space for disposing the wafer, and a heat flow

transmitting section joined to the heat flow control section,

for transmitting heat to the wafer disposed in the space, and

a heat resistance $R_g$ at a flat or curved surface where the

heat flow control section and the heat flow transmitting

section are close to each other is uniform.


2.    The vapor-phase growth apparatus as claimed in claim

1, wherein a ratio $R_2/R_1$ is not less than 0.8 to not more than

1.2, where $R_1$ is a heat resistance for a heat transfer route

from a rear surface of the heat flow transmitting section to

the front surface of the wafer, and $R_2$ is a heat resistance for

a heat transfer route from the rear surface of the heat flow transmitting section to a front surface of the heat flow control section.

3. The vapor-phase growth apparatus as claimed in claim 1 or 2, wherein the heat resistance $R_g$ is not less than $1.0 \times 10^{-6}$ $m^2K/W$ to not more than $5.0 \times 10^{-3}$ $m^2K/W$.

4. The vapor-phase growth apparatus as claimed in any one of claims 1 to 3, wherein a clearance distance between the heat flow control section and the heat flow transmitting section is uniform and the clearance is in a range of 0.001mm to 1mm.

5. The vapor-phase growth apparatus as claimed in any one of claims 1 to 4, wherein the heat flow control section is made of a material having a coefficient of thermal conductivity which is not less than 0.5 times to not more than 20 times that of the wafer disposed on the heat flow transmitting section.

6. The vapor-phase growth apparatus as claimed as claimed in any one of claims 1 to 5, wherein the heat flow transmitting section is made of a material having a coefficient of thermal conductivity which is not less than 50W/mK to not more than 450W/mK.

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7.    The vapor-phase growth apparatus as claimed in any one of claims 1 to 6, wherein the heat flow control section is made of a material selected from a group consisting of amorphous carbon, aluminum nitride, graphite, silicon, silicon carbide, molybdenum, pyrolitec boron nitride, and alumina, and

the heat flow transmitting section is made of a material selected from a group consisting of molybdenum, graphite, gold, and silver.

8.    A vapor-phase growth method comprising:

using a vapor-phase growth apparatus comprising a reaction furnace which is hermetically closable, a wafer container disposed in the reaction furnace, for disposing a wafer at a predetermined position, a gas supply member for supplying a source gas toward the wafer, and a heating member for heating the wafer; and

forming a thin film on a front surface of the wafer by supplying the source gas in a high temperature state while the heating member heats the wafer in the reaction furnace through the wafer container,

wherein a temperature difference between a front surface of the wafer container and a front surface of the wafer is within 2°C in the forming.
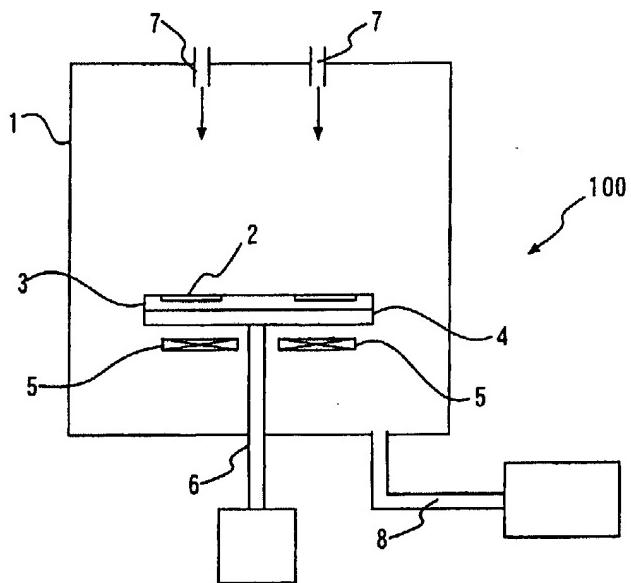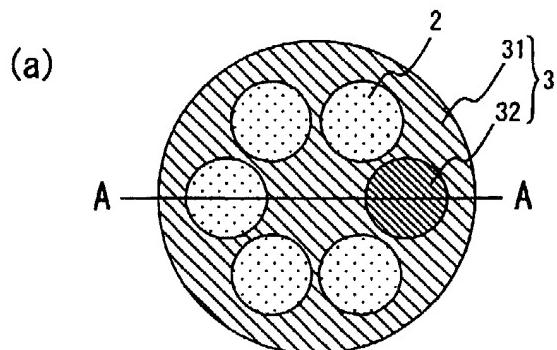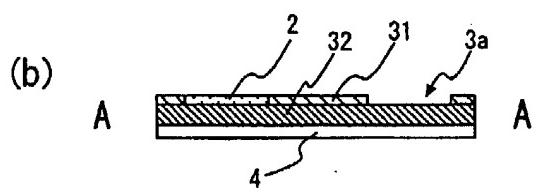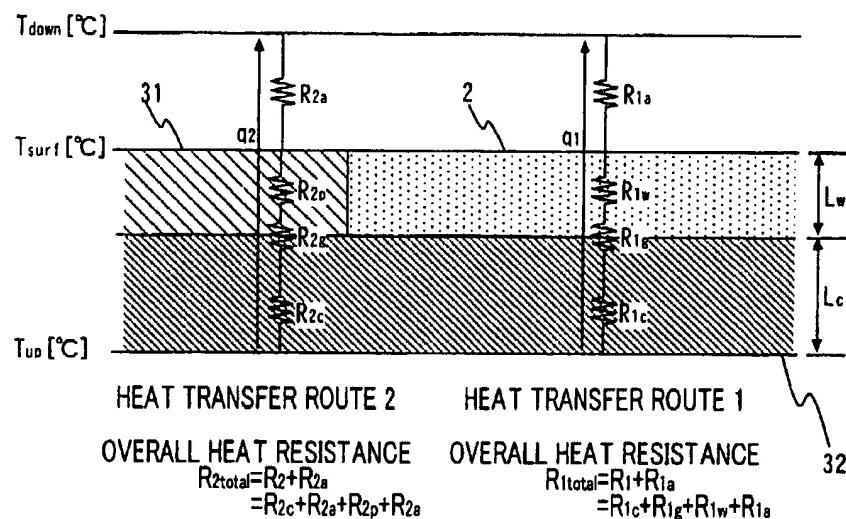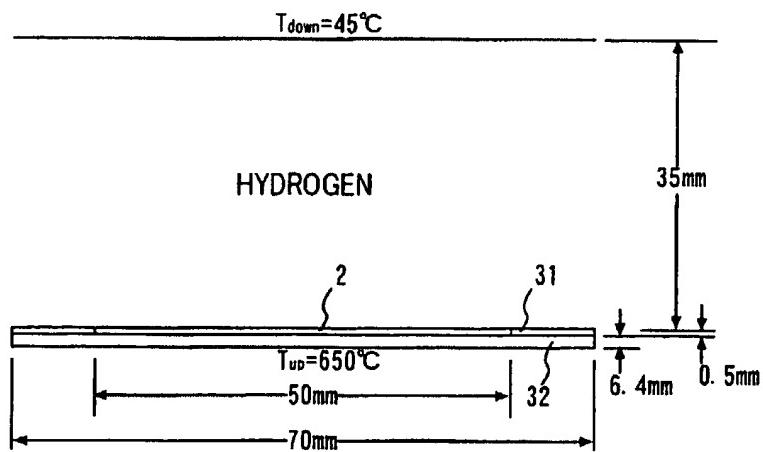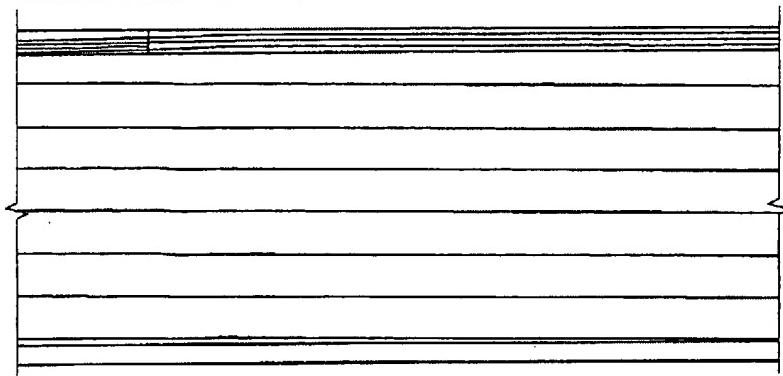
*FIG.1*



(a)

*FIG.2*



(b)

# FIG.3



HEAT TRANSFER ROUTE 2          HEAT TRANSFER ROUTE 1

OVERALL HEAT RESISTANCE        OVERALL HEAT RESISTANCE
$R_{2total}=R_2+R_{2a}$              $R_{1total}=R_1+R_{1a}$
$=R_{2c}+R_{2a}+R_{2p}+R_{2a}$           $=R_{1c}+R_{1g}+R_{1w}+R_{1a}$

# FIG.4

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# FIG.5

RANGE : 634℃-638℃/40DIV
RESOLUTION : 0. 1℃/DIV

# FIG.6

RANGE : 636℃-640℃/40DIV
RESOLUTION : 0. 1℃/DIV

# *FIG.7*



# *FIG.8*

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(a)



*FIG.9*

(b)



*FIG.10*



HEAT TRANSFER ROUTE 2          HEAT TRANSFER ROUTE 1

OVERALL HEAT RESISTANCE       OVERALL HEAT RESISTANCE
$R_{2total}=R_2+R_{2a}$              $R_{1total}=R_1+R_{1a}$
$\quad =R_{2c}+R_{2a}$                 $\quad =R_{1c}+R_{1g}+R_{1w}+R_{1a}$
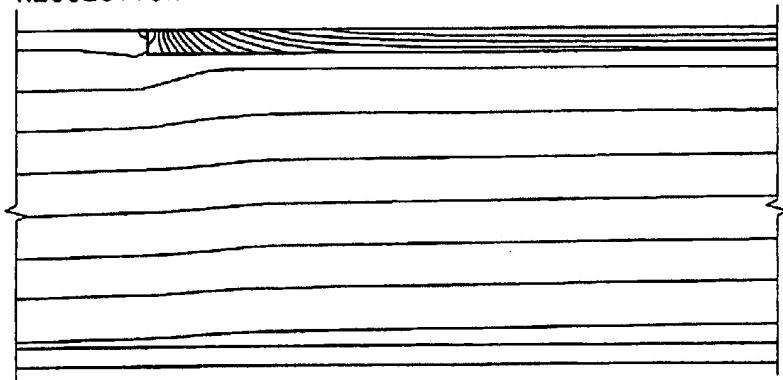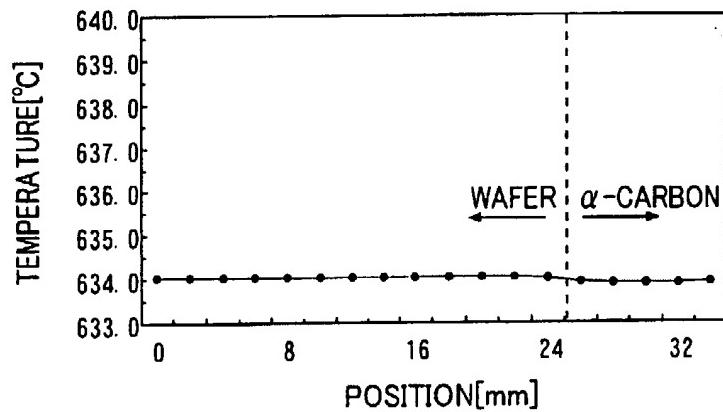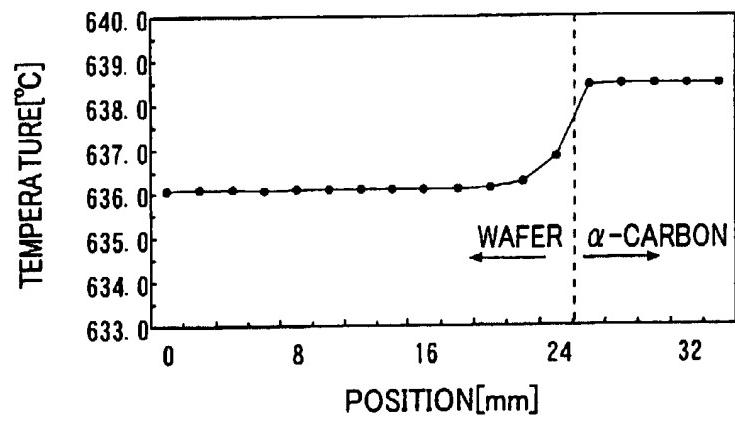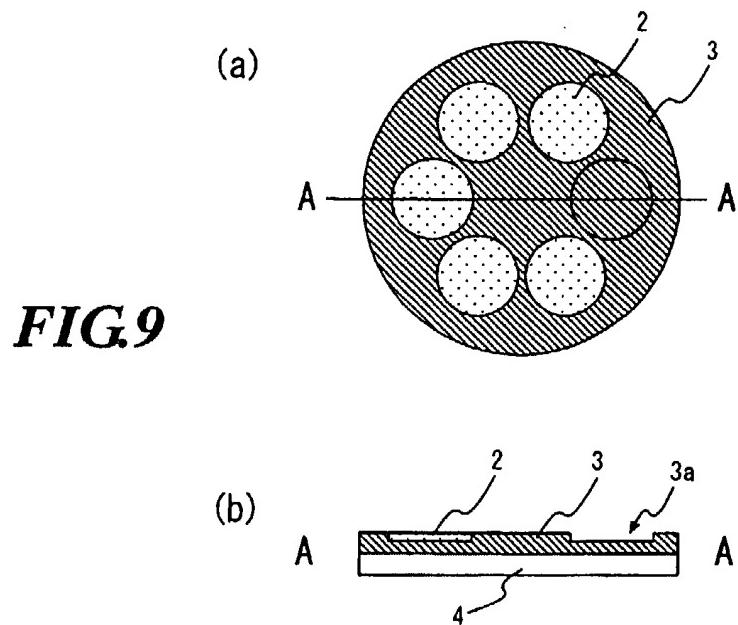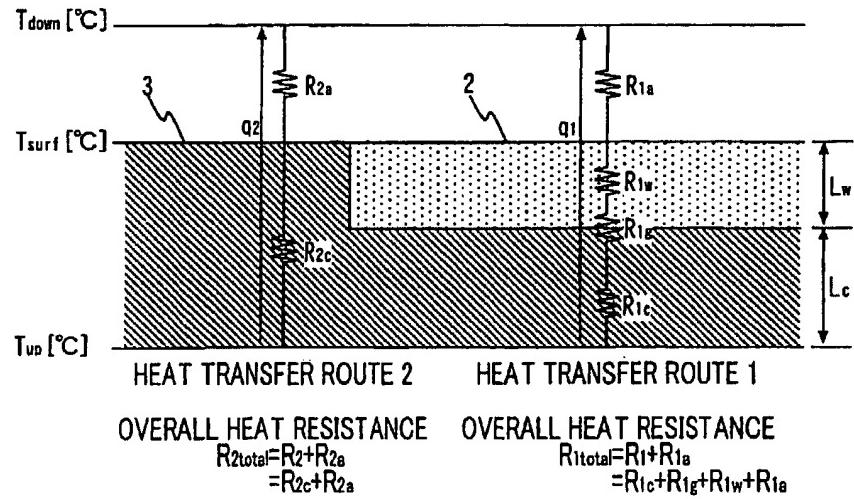
## Patent Abstracts of Japan

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| | | |
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| PUBLICATION NUMBER | : | 59044818 |
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| APPLICANT | : | TOSHIBA CORP; |
| | | |
| INVENTOR | : | KUBOTA HIROYASU; |
| | | |
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| | | |
| TITLE | : | HEATING BLOCK |
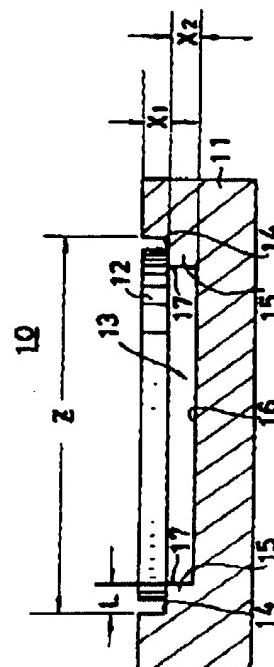
ABSTRACT : PURPOSE: To prevent a processed material from slipping and make vapor phase growth easy by a method wherein an opening which has a diameter a little bit larger than that of the processed material is formed on a block and inside the opening an approximately circular step by which the processed material is supported is provided.

CONSTITUTION: An opening 13 which has a diameter Z a little bit larger than that of a processed material 12 such as a semiconductor wafer is formed on a prescribed domain of a basic body 11 of a heating block 10. An approximately circular step 15 which is protruded inside the opening 13 is formed in order to provide an approximately circular supporting surface 14 which supports the processed material 12 from the bottom. The basic body is made of a material such as carbon and of a carbon silicate layer of thickness approximately 100μm which is formed on the carbon material.

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明　　　細　　　書

1. 発明の名称

　　加　熱　基　台

2. 特許請求の範囲

　基体の所定領域に被処理体の径よりも僅かに
大きい径の開口部を有し、該開口部の内壁に階
段状に前記被処理体の支持面を形成して突出し
た段部を有し、かつ、該開口部内に略平坦面か
らなる床面を有してなることを特徴とする加熱
基台。

3. 発明の詳細な説明

　〔発明の技術分野〕

　本発明は、加熱基台に関する。

　〔発明の技術的背景とその問題点〕

　従来、シリコンウエハ等の被処理体に気相成
長処理を施す場合、例えば、第 1 図に示す如く
シリコン等からなる基体 1 に球面状の凹部 2 を
形成し、この凹部 2 に半導体ウエハ等の被処理
体 3 を載置し、これを所定の炉内に設置するこ
とにより行っている。しかしながら、このより

な加熱基台 4 を用いるものでは、被処理体 3 の
径が大きくなるとこれに合わせて凹部 2 の径を
大きくすると、気相成長処理の際のスリップの
発生率が高くなる欠点がある。また、第 2 図に
示す如く、凹部 2 の開口部に被処理体 3 の周縁
部を支持する平坦な支持段部 2 a を形成した加
熱基台 5 も開発されている。この加熱基台 5 は、
第 1 図に示す加熱基台 4 に比べてスリップの発
生を抑えることができるが、依然被処理体 3 の
径が大きくなると、十分にスリップの発生を抑
えることができなかった。

　〔発明の目的〕

　本発明は、被処理体にスリップが発生するの
を阻止して、所望の気相成長処理を容易に施す
ことができる加熱基台を提供することをその目
的とするものである。

　〔発明の実施例〕

　以下、本発明の実施例について図面を参照し
て説明する。

　この加熱基台 1 0 は、基体 1 1 の所定領域に

半導体ウエハ等からなる被処理体12の径よりも僅に大きい径Zの開口部13を有している。開口部13の内壁には、被処理体12の下面を支持する略環状の支持面14を有して開口部13内に突出した段部15が形成されている。段部15で囲まれた開口部13の底面16は、略平坦面に形成されている。基体11としては、カーボン材料等からなる基材の表面にC.V.D.(Chemical Vapor Deposition)法等により炭化ケイ素を100μm程度形成したものを使用するのが望ましい。炭化ケイ素を表面に形成するのは、後述する気相成長処理の際の温度が1000～1250℃と高温に達した場合にカーボン材料からなる基材から、不純物が放出されるのを防止するためである。開口部13の径Zを被処理体12の径よりも僅に大きくしたのは、開口部13内への被処理体12の出入操作を容易にするためと、気相成長処理の際の温度によって膨張した被処理体12と基体11とが接触して、被処理体12に熱歪が生じるのを防止するため

である。支持面14の幅しは、被処理体12の直径の約5%の幅の環部が支持面14で支持されるように設定するのが望ましい。基体11の裏面から支持面14までの距離X₁は、被処理体12の内厚にほぼ等しく設定するのが望ましい。支持面14から底面16までの距離X₂は、被処理体12の大きさに応じて適宜設定するのが望ましい。例えば、被処理体12であるウエハの径が100mmφの場合には、50～100μmに設定するのが望ましい。この底面16までの距離X₂を深くしすぎると、基体11から被処理体12に伝導する熱量が不十分になり、被処理体12の温度を所定温度に設定できない。また、この底面16までの距離X₂が浅すぎると、加熱された被処理体12全体の温度を均一に保持できず、熱歪を発生したり或は欠陥を発生する原因となる。また、この底面16までの距離X₂は、気相成長処理の際の加熱温度が、処理ガスとしてSiHCl₃を使用した場合は1150℃、SiH₂Cl₂を使用した場合は1100℃、SiH₄

を使用した場合は1000℃と異なるので、処理ガスの種類に応じても適宜設定するのが望ましい。また、底面16の平坦度は、加熱された底面16の熱が被処理体12の下面全域に亘って均一に伝わるように、被処理体12の下面と略平行に設定するのが望ましい。底面16に多少の凹凸が形成されていたり、或は、湾曲部が形成されていても、底面16から被処理体12の下面に均一に熱を伝達できればよい。また、段部15は、開口部13の内壁から開口部13内に向つて突出しで、被処理体12を高い水平度で支持できるものであれば良い。段部15が連続的に環状に連つていることを特に要しない。また、底面16から立設した段部15の側面17は、底面16から被処理体12への均一な熱伝達作用を助長するように、底面16に対して約90°の急峻な角度で立設していることが望ましい。

而して、このように構成された加熱基台11によれば、開口部13内に被処理体12である

ウエハを、その下面の環部が支持面14にて支持されるようにして収容し、これを所定の処理ガスが満された気相成長処理炉内に載置して気相成長処理を施す。炉内の加熱処理によって、まず、基体11全体の温度が急上昇する。この熱は、基体11の底部から支持面14を介して被処理体12の環部に伝導される。被処理体12の周縁部では、段部15が底面16に対して急峻な角度で立設し、支持面14に蓄熱しているので、急激に温度上昇が起き、被処理体12全体を加熱する熱が蓄えられる。蓄えられた熱は、被処理体12の周縁部からその内厚全体の領域に亘って被処理体12の中心に向つて拡散する。この被処理体12内での熱拡散の際に、被処理体12の表面は、炉内雰囲気に接した状態であり、裏面は、開口部13の下部の中空部に接した状態になつているので、基体11外からの熱の伝達は殆んど無視され、被処理体12全体の温度が極めて均一な状態で上昇する。その結果、被処理体12の環部にあえて熱中的により

ップを発生させ、段部を除いた領域にスリップが発生するのを阻止することができる。しかも、被処理体12の温度上昇に伴つて発生した熱歪は、被処理体12の周辺部の領域に吸収されるので、更に、被処理体12の中心部でのスリップの発生を阻止する作用を高めることができる。

因に、第3図に示す如く、基体11の裏面から支持面14までの厚さ $X_1$ を650μm、支持面14から床面16までの距離 $X_2$ を80μm、床面16の大きさを90mmφ、開口部13の径 $Z_1$ を102mmφに設定した加熱基台10を用いて、この開口部13内に被処理体12である直径100mmφのウエハを収容し、気相成長処理を施したところ支持面14に接触しなかつた領域（被処理体12の周辺部を除いた領域）では、シャトルエッチング検査により、欠陥の有無を調べたところ、スリップの発生はほとんど見られなかつた。この場合のスリップの発生数を被処理体12の直径方向に沿つて調べたところ、第4図(A)に示す通りであり、被処理体12の周

辺部に集中していることが判る。これに比べて球面状の開口部を有する従来の加熱基台では、第4図(B)に示す如く、被処理体の性度全域に亘つて多数のスリップが発生していることが判る。更に、実施例の加熱基台10に比べて段部15の突出量を多くして被処理体12の中心から直径にして約60mmφの領域が支持面と接触しないようにした加熱基台を使用すると、スリップの発生数は第4図(C)に示す如く、被処理体12の中心から直径約60mmφの領域を除いた周辺部全域で多数のスリップが発生していることが判る。つまり、実施例の加熱基台10では、床面16を性度平坦にし、床面16に対して急峻に立ち上がつた段部15の支持面14で被処理体12を支持することにより、支持面14に接触した被処理体12の領域にのみスリップを集中的に発生させ、支持面14に接触しない領域には、スリップを事実上発生させないようにすることができることが判る。

〔発明の効果〕

以上説明した如く、本発明に係る加熱基台によれば、被処理体内にスリップが発生するのを阻止して、所望の気相成長処理を容易に施すことができる等顕著な効果を奏するものである。

4. 図面の簡単な説明

第1図及び第2図は、従来の加熱基台の断面図、第3図は、本発明の一実施例の断面図、第4図(A)乃至同図(C)は、スリップの発生数と被処理体の位置との関係を示す説明図である。

10…加熱基台、11…基体、12…被処理体、13…開口部、14…支持面、15…段部、16…床面、17…側面。

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第 1 図



第 2 図



第 3 図



第 4 図

(A)　　　　(B)　　　　(C)